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ILLINOIS GEOLOGY FROM SPACE

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ILLINOIS STATE GEOLOGICAL SURVEY

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INTRODUCTION

For more than 100 years man has attempted to get a better view of the earth's surface by moving himself or his instruments above the earth. Aerial photographs were first taken from balloons at about the time of the Civil War, and cameras were carried aloft in the earliest aircraft flights. The development of aircraft in the early part of the 20th century led to the first practical methods of providing views of the earth's surface from a vantage point useful to geologists. Methods of making geographic, topographic, and geologic maps from aerial photographs have been developed to a high degree since 1930, and such maps have become routine tools in geological investigations. The standard photographic products used by geologists for many years have been large-scale (usually 1:20,000) high-resolution photographs taken by the U.S. Geological Survey from intermediate altitudes (generally less than 20,000 ft, 6.1 km) for topographic mapping. These photos provide detailed information about a few square miles, but attempts to map larger regions at smaller scales involve large numbers of photographs, high costs, and photo mosaics that are difficult to use because of the variations in lighting and contrast from photo to photo.

Synoptic views (views of a large area at a small scale) became possible with the development of rockets, which could lift cameras above the atmosphere. The first geologic use of synoptic views from very high altitudes was made by Merifield (1964). Orbital manned spacecraft provided the first means of obtaining large numbers of photographs from space. During the early 1960's astronauts on Gemini, and later those on the orbital Apollo missions, took more than 2,000 photographs, mostly with hand-held cameras of the 70 mm format. A collection of these has been published by NASA (1967), and their geologic use has been discussed by Lowman (1969) and Lowman and Tiedemann (1971). The regions covered by these early orbital missions were limited to a narrow band around the equator. Polar orbiting satellites, those that go north-south rather than east-west, in time cover the entire earth. The earliest weather satellites, like Nimbus 1, which was launched in 1964, carried imaging equipment into space. Unlike the film returned by the astronauts, the Nimbus satellite could transmit continuous images. These images, similar in some respects to television images, are of low resolution but, because of their synoptic view, have been useful geologically (Lathram, 1972).

By the late 1960's it was apparent that considerable information for scientists in a wide range of disciplines could be obtained from orbital satellites Soil scientists, agriculturists, oceanographers, cartographers, land-use planners, foresters, and others, as well as geologists, required synoptic data in large volumes. The Earth Resources Technology Satellite (ERTS) program was established to meet the expected demand. ERTS-1 is an experimental unmanned polar orbiting satellite that transmits image data to ground stations, where they are converted to photograph-like images. This satellite was launched on July 23, 1972, and is still (November 1974) transmitting data. At least one additional experimental satellite of an improved capability, ERTS-B, is planned. There is the possibility of establishing a continuous operational satellite system in the future.

During early 1973, NASA launched the Skylab orbiting laboratory, which was manned by three teams of astronauts before being abandoned in February 1974. One of the experiments conducted by the astronaut teams was the Earth Resources Experiment Package (EREP), which consisted of a system of seven cameras that provided high-resolution black and white or color photographs. The Skylab orbit is diagonal and covers most of the globe; hence more areas were photographed than during the earlier orbital manned missions.

To date, ERTS-1 has provided cloud-free images for all parts of the United States and for three-fourths of the land surface of the rest of the world. Skylab and earlier manned missions photographed a much smaller portion of the land surface. In addition, scattered high-altitude (50,000 ft, 20 km) synoptic aerial photographs have become available as a result of various NASA-sponsored investigations of the usefulness of ERTS and Skylab data.

Geologists have largely made use of these new data in the way that they have been accustomed to using aerial photographs. The synoptic views provided by the small-scale, uniformly illuminated views are valuable for surficial geologic mapping. A single scene covers a wide variety of terrain, geology, and land-use types, and is presented under nearly optimum viewing conditions that emphasize the contextural relations of surface features. Enhancement by computer processing and photographic techniques has been used to get more information from data from space platforms.

The purpose of this paper is to review the availability of ERTS images and Skylab and high-altitude aircraft photographs of Illinois and to discuss their use and value to the geologist. These images and photographs are also of great value to soil scientists, agricultural experts, foresters, engineers, cartographers, local and regional planners, limnologists, hydrologists, highway planners, and others. General reviews of the value of ERTS images to these and other specialists can be found in publications by NASA-Goddard Space Flight Center (Finch, 1972; Freden, Mercanti, and Becker, 1973; Freden, Mercanti, and Witten, 1973; Freden and Mercanti, 1973; Freden, Mercanti, and Friedman, 1974a, 1974b; Freden, Mercanti, and Becker, 1974), the American Society of Photogrammetry (1972), and Anson (1973). A useful review of geological applications of ERTS and Skylab data is available in Short and Lowman (1973).

EARTH RESOURCES TECHNOLOGY SATELLITE (ERTS)

The first of two proposed ERTS satellites was launched into a polar orbit on July 23, 1972. Since then, more than 100,000 photograph-like images covering more than 80 percent of the earth's land surface have been returned. ERTS-1 is in a nearly circular orbit at an altitude of 565 miles (910 km), where it circles the earth 14 times a day and images about 188 scenes. The orbit is sun-synchronous, that is, it crosses the equator at the same local sun time, about 9:30 a.m., each orbit. For example, if the satellite crosses the equator over the mouth of the Amazon River at 9:30 a.m. local sun time on one orbit, the next orbit will take the satellite over eastern Ecuador about 103 minutes later, again at 9:30 a.m. local sun time, the earth having rotated that distance in the 103-minute orbital period. This arrangement results in a constant sun angle for all images taken at a particular latitude on a particular day. This constant and even lighting (varying only by season) is invaluable in making ERTS images a useful tool. The satellite passes along the same orbital track once every 18 days. Repetitive images thus obtained are very valuable in studying seasonal and temporal changes.

Sensors

The ERTS-1 satellite contains seven imaging instruments. Three, called the Return Beam Vidicon (RBV), were turned off early in the flight because of electrical failure. All subsequent images have been taken with a four-element multispectral scanner (MSS). This device consists of a moving mirror that resolves a small area on the earth's surface (about 1 acre) and projects it to an array of sensors that are sensitive to various wavelengths of light. The sensors record the intensity of light in each wavelength reflected by that one acre of surface. These data are then transmitted to earth or stored on tape for later transmission. Images are made for each of the four MSS bands (table 1) by recording the light-intensity data on photographic film point by point. The result is a photograph-like image made of more than a million individual elements, called pixels. Each image shows the relative intensity of reflected light in a particular wavelength. These images cover an area 114 miles (185 km) on a side, or about 13,000 square miles (34,225 sq km). The resolution of ERTS-1 images ranges from 820 feet (250 m) for low-contrast features to as much as 300 feet (91 m) for objects of maximum contrast. The wavelengths of each band of the MSS are shown in table 1.

TABLE 1 - WAVELENGTHS OF LIGHT RECORDED BY SENSORS IN THE FOUR-BAND MSS OF ERTS-1

Band 4	0.5-0.6 micrometers	Blue-green
Band 5	0.6-0.7 micrometers	Red
Band 6	0.7-0.8 micrometers	Infrared
Band 7	0.8-1.1 micrometers	Infrared

The resolution of the ERTS-1 images has sufficient detail for agricultural field patterns, large geologic features, and gross land-use patterns to be seen and mapped. Obviously, individual houses and other small features cannot be resolved. Many of the data are available on computer-compatible tape and can be directly processed and enhanced because they are taken by the satellite in digital form.

Another value of ERTS-1 images is that they can be compiled into mosaics to which geometric corrections are applied so that they rival conventional maps for planimetric accuracy at the scale of 1:250,000 and smaller. A map can be made from an ERTS-1 frame which meets national map accuracy standards at an enlargement of up to 40 x 40 inches (102 x 102 cm).

Images of Illinois

The multispectral scanner is a continuously scanning instrument. The data taken along the flight line are arbitrarily broken up into square images wherein the ground track increment is approximately equal to the lateral scan distance. For each orbital pass (every 18 days), these images are centered over the same point with an accuracy of ± 15 km. Twelve of the nominal image center points cover parts of Illinois (fig. 1). Approximately 15 percent side overlap is allowed and a small amount of along-track repetition of scan lines is permitted in the latitude of Illinois. Several cloud-free or nearly cloud-free images have been taken over each nominal center point in Illinois (see appendix for list and dates). These images are available for the cost of reproduction from: EROS Data Center, Sioux Falls, South Dakota 57918. The EROS Data Center is an arm of the U.S. Geological Survey, U.S. Department of the Interior. The images should be ordered by frame number and band, there being four bands or images for each frame. Frames are filed at EROS and at the Illinois State Geological Survey according to nominal center points. The data center will provide a current price list and order form upon request. Nine by nine inch (22.9 x 22.9 cm) paper prints at present cost $2.00 each. Besides 70 mm positive and negative transparencies and 9 x 9 inch paper prints (the common products), enlargements to 40 x 40 inches (102 x 102 cm) can be obtained for each

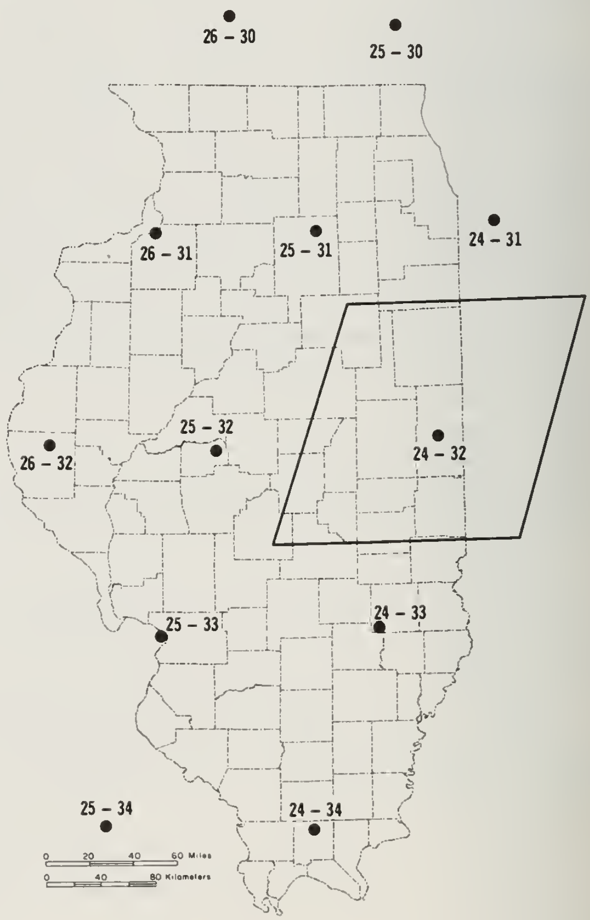


Fig. 1 - Nominal image centers for Illinois and the area covered by a typical ERTS-1 multispectral scanner frame. The numbers are those used by the EROS Data Center to index ERTS images.

frame. False-color composites, imitating color infrared photography, are also available, as are 9 x 9 inch film transparencies and other products such as computer-compatible tapes. ERTS images and other remote sensing data for Illinois are on file in the Illinois Geological Survey Remote Sensing Files and may be examined at the Survey offices, but the Survey does not reproduce images.

Geology

ERTS images in the Illinois Geological Survey Remote Sensing Files have been evaluated for geologic use. Several factors limit the usefulness of these images in Illinois. First, Illinois has been extensively mapped, both geologically and topographically, at various scales. U.S. Geological Survey 15-minute quadrangle topographic maps are available for the entire state, and 7½-minute quadrangle maps for a large portion of the state. Geologic maps at various scales have been made (for example, Willman and others [1967], Willman and Frye [1970], Willman [1971], Baxter and Desborough [1965], Baxter, Desborough, and Shaw [1967], Baxter, Potter, and Doyle [1963], and many others). Therefore, the new technology provides little additional information.

Further, the surface of Illinois is generally of low relief, and all but a small part is covered by 50 to 400 feet (15 to 122 m) of glacial drift that masks almost all bedrock features. Surficial features of the drift surface, such as moraines, ridges of drift, and abandoned glacial lakes, are low-relief, low-contrast features, yet some can be seen on ERTS images.

Additionally, the ground surface of Illinois is intensively farmed, and during much of the year heavy vegetation or snow hides surficial features. The best images for geologic study have been obtained in the spring when fields are bare or freshly planted. Soil textures associated with features of the glacial drift appear most clearly then.

For this report two images have been selected for detailed examination and comparison of ERTS images and Skylab photographs; these are the Champaign-Urbana area in east-central Illinois, where glacial drift features predominate, and extreme southern Illinois, which is characterized by complicated bedrock structures (fig. 2). ERTS images are also being used to determine sediment-dispersal patterns related to erosion along Illinois' Lake Michigan shoreline (Jacobs and DuMontelle, 1974).

Champaign-Urbana, Illinois

Images of the four MSS bands of ERTS frame 1322 16051 taken over east-central Illinois June 10, 1973, are illustrated by figure 3. MSS band 4 in the blue-green visible range (table 1) is characterized by less clarity than the others because this wavelength is most affected by atmospheric haze and water vapor. Penetration of water bodies is greatest on band 4, however; and this band can be used in the study of sediment-laden water in lakes. Cultural artifacts and clouds can be identified on band 4, but are usually not as clearly visible as on band 5. Band 5, in the visible red range, shows cultural features, roads, built-up areas, and disturbed areas to best advantage. Sediment in water also shows up well on this band. Geologic features, such as soil patterns and

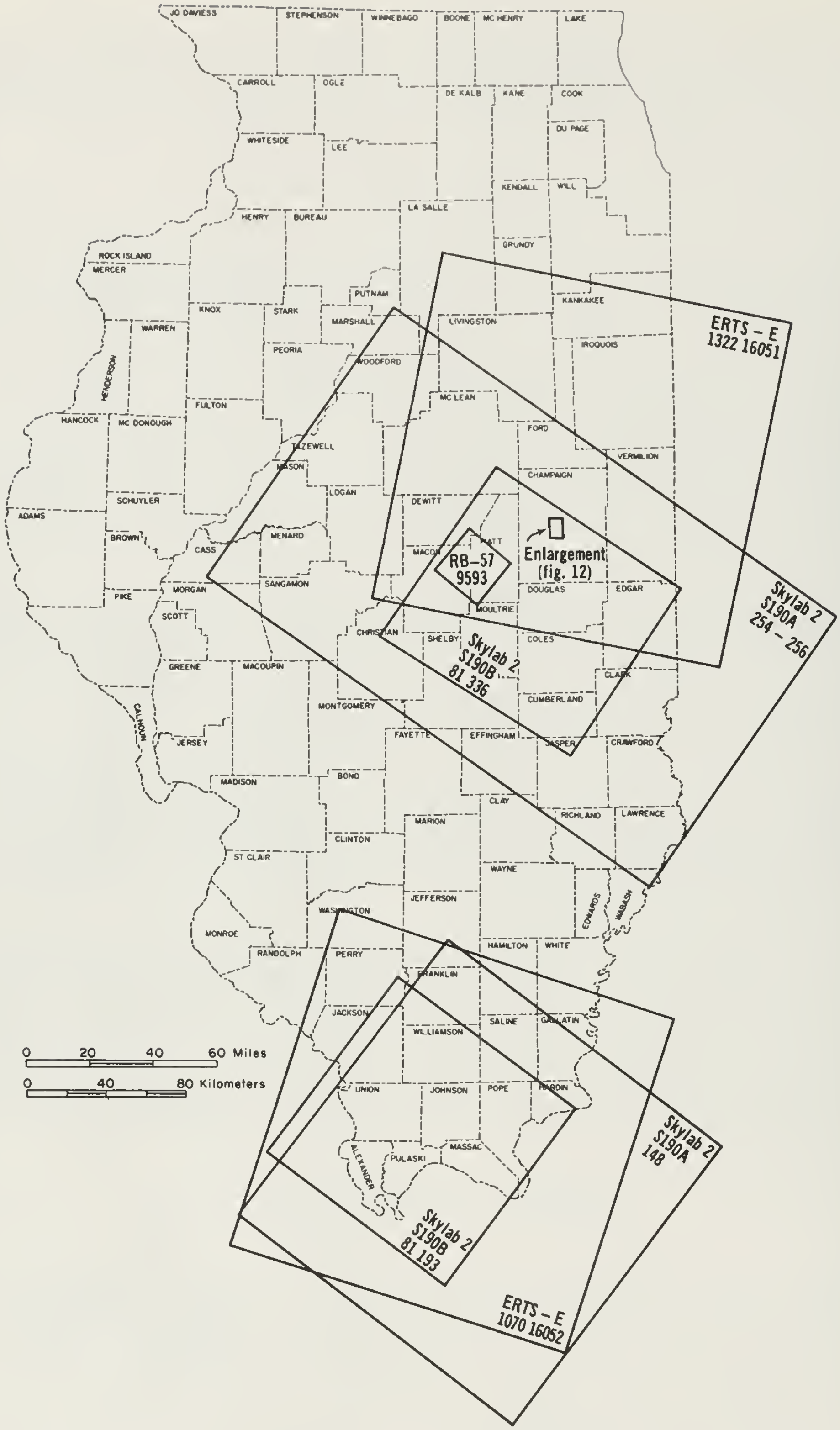


Fig. 2 - Areas covered by ERTS images and Skylab and high-altitude photographs illustrated in this report.

structural lineaments, show well, but it is difficult to separate water from land on band 5. Bands 6 and 7 are sensitive to light in the infrared range and appear similar. Water appears very dark, while vegetation and the land surface appear as lighter tones. Band 7 is the best band for mapping the outline of water bodies. Bands 5 and 7 are very commonly used together in geologic studies.

Geologic features visible on the ERTS images of east-central Illinois include the looping low ridges associated with presumed terminal glacial moraines (fig. 4). The moraines are visible because lighter colored, well-drained soils on the ridges are in contrast with the darker, more poorly drained soils on the intervening drift plains. Linear features, such as straight stream courses or connecting alignments of streams, are visible. Drainage patterns give a good indication of underlying geology, even in a drift-covered region.

Only a few major roads and the larger towns and cities can be resolved on ERTS images. Detailed evaluation is limited by the low resolution.

Southern Illinois

ERTS frame 1070 16052 (October 1, 1972) includes the entire southern tip of Illinois (fig. 5). This is an unglaciated region where bedrock stratigraphy and structure control the topography. A generalized line can be drawn between the drift-covered region to the north and the bedrock area to the south (fig. 6). The area of Silurian and Lower Devonian rocks along the Mississippi River just above its confluence with the Ohio stands out clearly. The Cache Valley, an abandoned segment of the Ohio, is clearly visible. Surficial soil textures north of the Cache Valley reflect shallow Paleozoic bedrock and are different from those south of the Cache, which reflect underlying coastal plain sediments of Cretaceous age. Lineaments extending across southern Illinois mark the position of the Ste. Genevieve Fault and the boundary between Valmeyeran (middle Mississippian) carbonates and Chesterian (upper Mississippian) and Pennsylvanian clastic rocks. Terraces and areas of older alluvium can be separated from the modern alluvial valley of the Ohio and Mississippi Rivers. Compare the bedrock boundaries on the sketch map (fig. 6) with those on the Geologic Map of Illinois (Willman and others, 1967) (fig. 7).

Other features visible on the ERTS images include Hicks Dome, which is a major structural feature in Hardin County, the Shawneetown Fault, and several areas of strip mining.

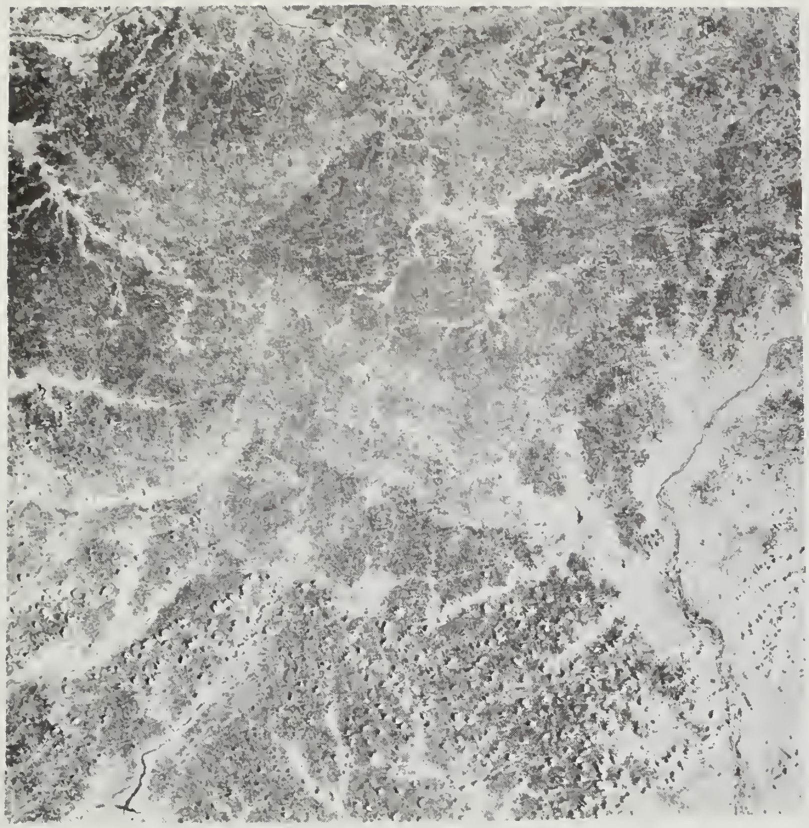
Value of ERTS

The ERTS-1 satellite and its planned successor, ERTS-B, provide low-resolution synoptic multispectral overviews of the earth's surface. Each point is imaged once in an 18-day cycle. The repetitive views are of great value in Illinois in studying dynamic phenomena, such as seasonal vegetation changes, agricultural practices, expansion of man-made artifacts, flooding, sediment dispersal, and erosion. In addition, the images have a high degree of planimetric accuracy. The data can be readily processed and enhanced by computer.

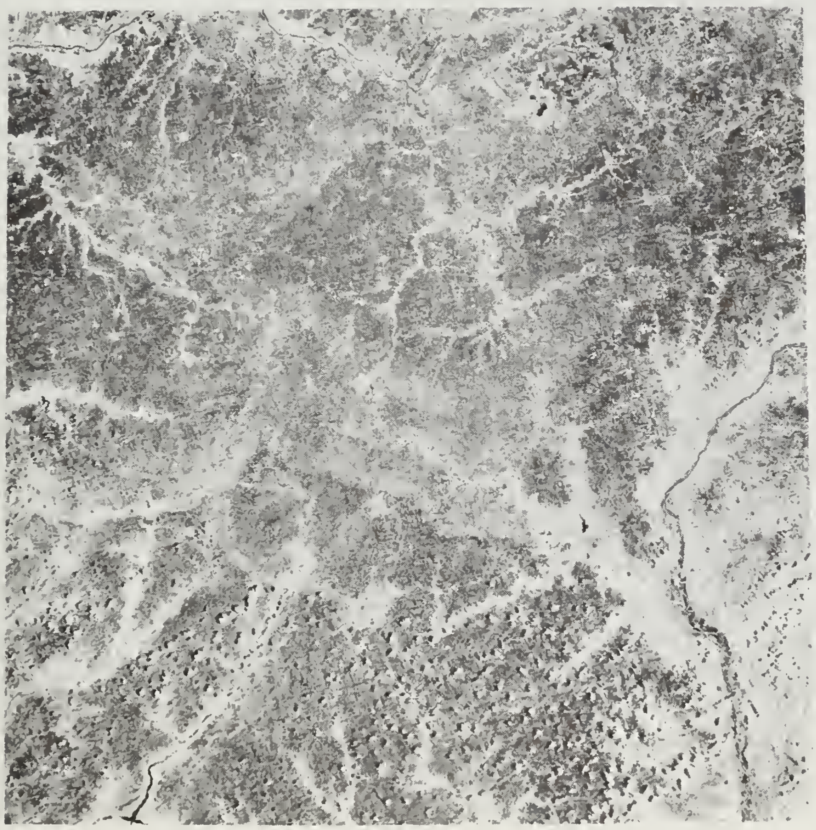
A

B

Fig. 3 - ERTS frame 1322 16051 covering east-central Illinois; four MSS bands,



C



D

A - MSS 4, B - MSS 5, C - MSS 6, D - MSS 7. Image taken June 10, 1973.

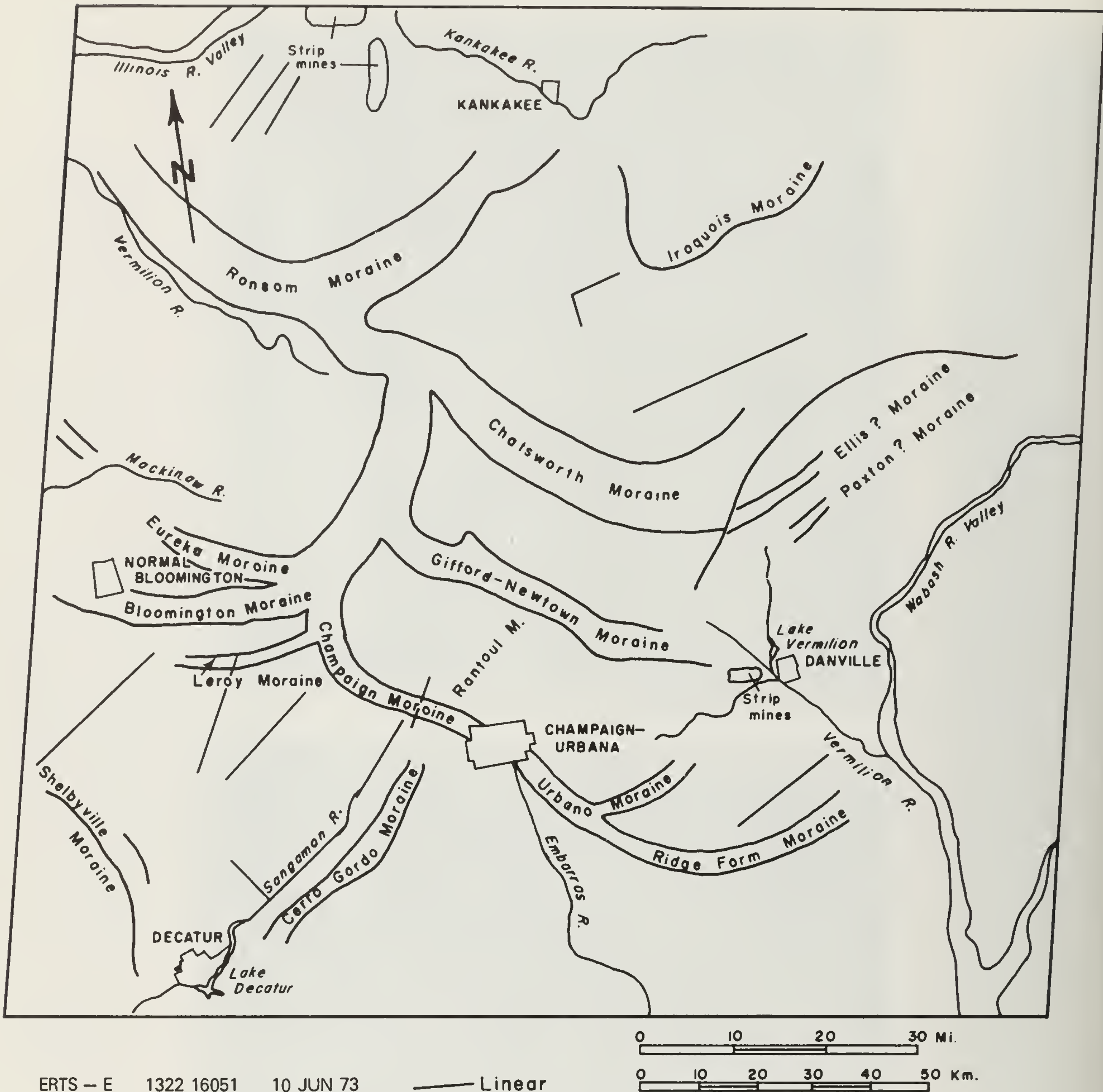


Fig. 4 - Geologic sketch map of east-central Illinois based on interpretation of ERTS frame 1322 16051, taken June 10, 1973.

Disadvantages of ERTS include the low resolution and cloud cover that reduces actual acquisition of images in Illinois to once every 36 days or less often.

In well-mapped areas, such as Illinois, the ERTS images have not produced much significant additional geologic information, and many surficial features known to exist and mapped by conventional methods cannot be seen on ERTS images. Illinois can, however, serve as a training area for mapping lesser known regions covered by glacial drift and intense agriculture (Morrison and Hallberg, in preparation).

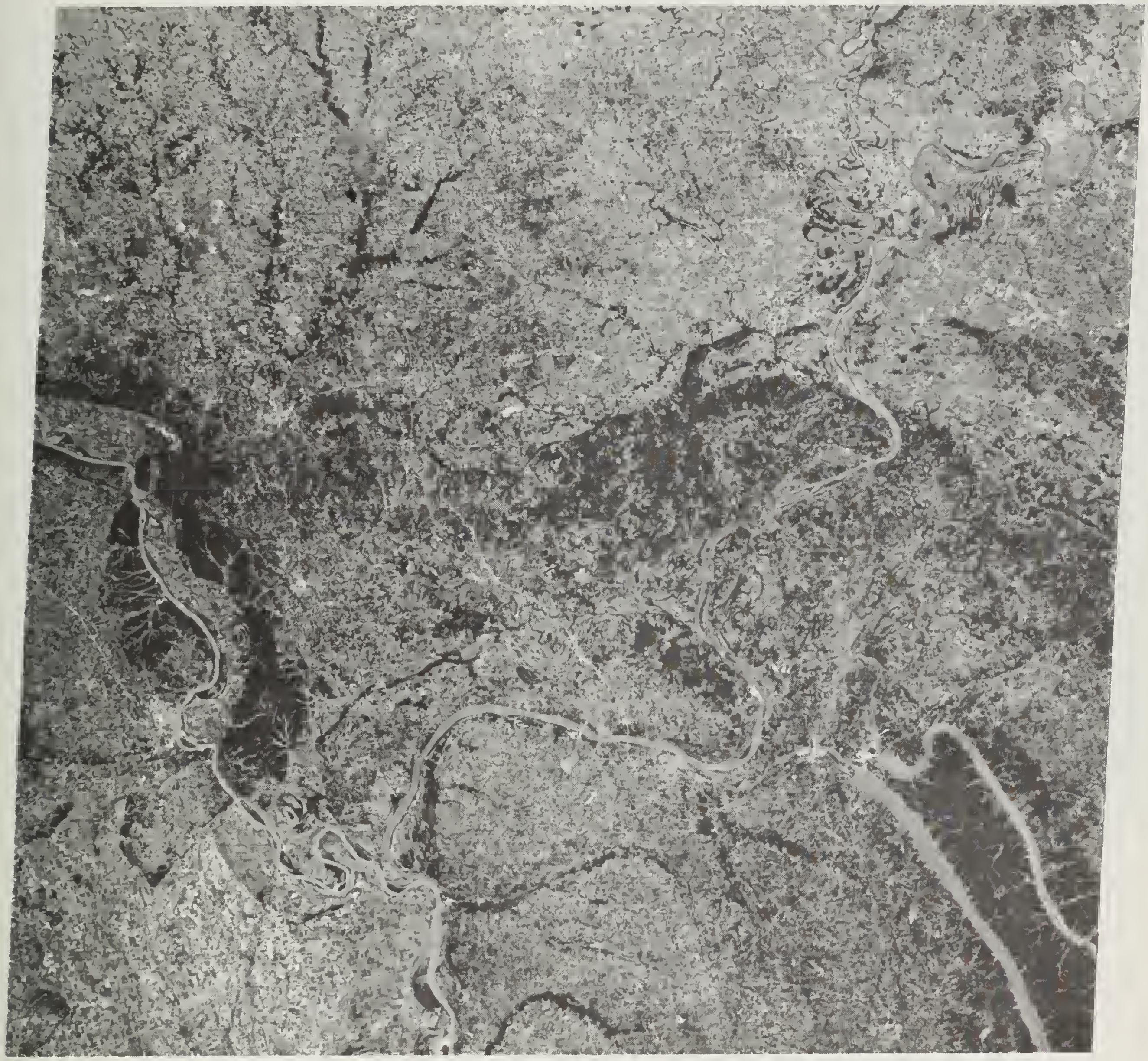
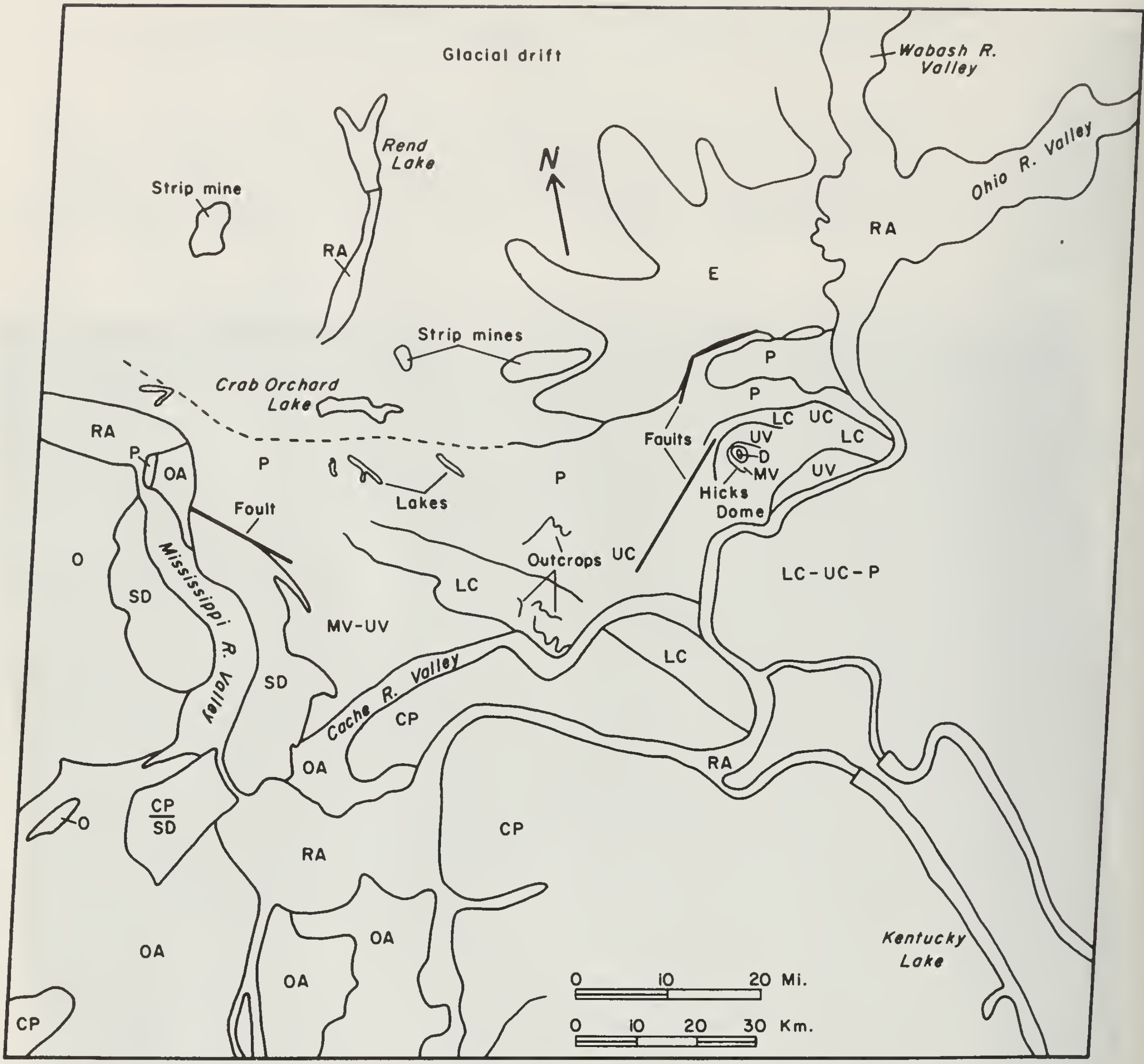


Fig. 5 - ERTS frame 1070 16052, taken October 1, 1972, over southern Illinois.



ERTS E 1070 16052 01 OCT 72

RA	Recent alluvium	Mississippian	
OA	Older alluvium	UC	Upper Chesterian
E	Equality Formation (lake deposits)	LC	Lower Chesterian
		UV	Upper Valmeyeran
CP	Coastal plain (Cretaceous–Tertiary)	MV	Middle Valmeyeran
		D	Devonian
		SD	Silurian – Devonian
P	Pennsylvanian	O	Ordovician and older

Fig. 6 - Geologic sketch map of southern Illinois based on interpretation of ERTS frame 1070 16052, taken October 1, 1972.

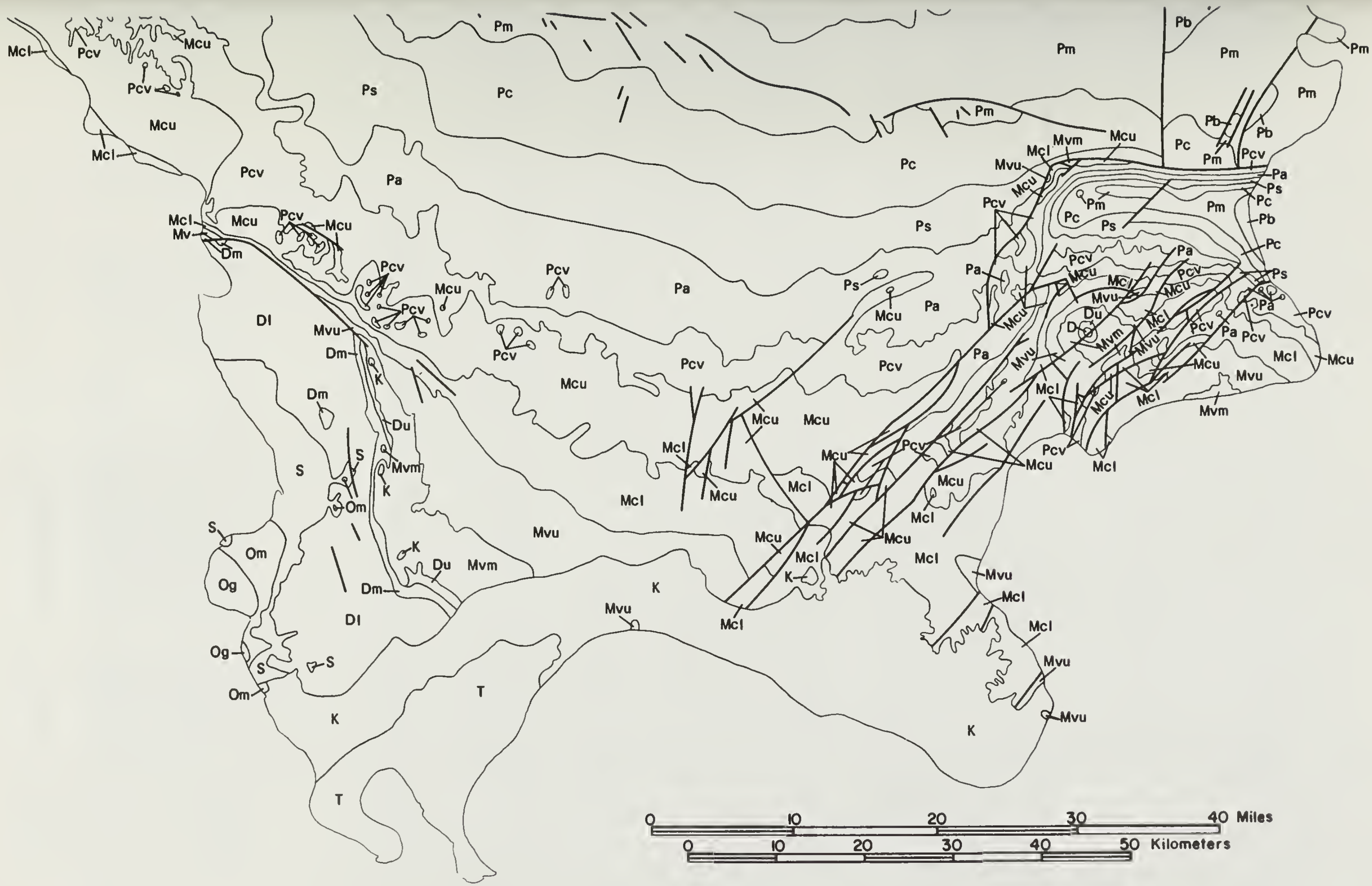


Fig. 7 - Adaptation of extreme southern Illinois portion of the Geologic Map of Illinois (Willman and others, 1967) for comparison with geologic sketch maps.

Symbols: T - Tertiary; K - Cretaceous; Pennsylvanian — Pb - Bond, Pm - Modesto, Pc - Carbondale, Ps - Spoon, Pa - Abbott, Pcv - Caseyville; Mississippian — Mcu - upper Chesterian, Mcl - lower Chesterian, Mv - Valmeyeran, Mvu - upper Valmeyeran, Mvm - middle Valmeyeran; D - Devonian, Du - Upper Devonian, Dm - Middle Devonian, Dl - Lower Devonian; S - Silurian; Ordovician — Om - Maquoketa, Og - Galena-Platteville.

SKYLAB

The Skylab orbiting space station was launched by NASA early in 1973. On the initial mission (Skylab 1), the space station was inserted into an equatorial orbit, but it was heavily damaged during launch. On the first manned mission (Skylab 2), the astronauts made a heroic effort and repaired the craft so that the mission could be completed. The first crew left the space station in early summer and was replaced by the Skylab 3 crew, who manned the station through the fall of 1973. A fourth Skylab manned mission was flown for a record length of time and ended early in 1974 with the return of the crew and final abandonment of the station.

The scientific value of earth and astronomical observations made by the nine Skylab astronauts is only now beginning to be evaluated, but it is believed to be great. Of value to geologists are the hard film photographs returned from the seven cameras in the Earth Resources Experiment Package (EREP). The S190A camera array contains six cameras. Four black and white cameras (table 2) photograph in wavelengths similar to the MSS bands on ERTS. Two additional cameras use high-resolution aerial color and color infrared film. These photographs are made on 70 mm film and cover an area 88 miles (142 km) on a side, a slightly smaller area than that covered on an ERTS frame (fig. 1). The seventh camera is the S190B 18-inch (457 mm) focal-length telephoto camera that covers an area only 60 miles (97 km) on a side from the nominal Skylab altitude of 269 miles (433 km). The S190B film is 4½ inches (114 mm) on a side and is high-resolution color film. The S190B coverage retains the synoptic overview, but the camera produces the highest quality photographs yet available from space for civilian use. Both the S190A and S190B photographs have considerably greater resolution (50 to 223 ft, 15 to 68 m) than ERTS images. Individual buildings that have high contrast with the surrounding area can be resolved on the S190B photographs. The author has located his own white-roofed house on these photographs. They can be enlarged several times while maintaining resolution.

The main disadvantage of Skylab photographs is discontinuous coverage. Only selected test sites were photographed on the limited film supply. The orbit cuts diagonally across the globe and does cover most of the United States, but

TABLE 2 - WAVELENGTHS PHOTOGRAPHED, FILM TYPE, AND RESOLUTION OF THE VARIOUS CAMERAS IN THE EREP EXPERIMENT ON SKYLAB

	Wavelength (micrometers)	Film	Expected resolution (ft)	(m)
S190A	0.5-0.6	Pan-X, b & w	99	30
	0.6-0.7	Pan-X, b & w	91	28
	0.7-0.8	Infrared, b & w	223	68
	0.8-0.9	Infrared, b & w	223	68
	0.5-0.88	Infrared, color	180±	55
	0.4-0.7	High-resolution, color	78	24
S190B	0.4-0.7	High-resolution, color	50	15

the local time of day when the photos were taken varied. One advantage of using overlapping Skylab photos is that true stereovision is possible.

The 70 mm photos produced by the S190A six-camera array have slightly less resolution than those from the 18-inch camera, but enlargements are good enough for detailed sketch maps to be made. Additional details can be provided by the 18-inch camera photos.

Champaign-Urbana Area

Figure 8 shows a frame made by the high-resolution color camera of the S190A; it was taken June 11, 1973. For comparison, a sketch map made from this frame and adjacent frames in east-central Illinois is shown in figure 9. Light to dark soil patterns associated with prominent glacial moraines can be seen and mapped. In the Skylab photos, unlike the ERTS images, soil textures associated with various till sheets can be distinguished and mapped. Other features include parallel drainage patterns on the slopes of some moraines, glacial lake basins, ridges of glacial drift, strip-mined areas, and major drainageways. Lineaments related to glacial deposition and possibly to bedrock structure can also be mapped.

These features can be seen in even greater detail on the photographs from the S190B camera. Enlargements of these photographs can be used for detailed study of soil textures related to surficial geologic units. One area underlain by a known, but unnamed and previously unmapped till unit in the northwest part of this area can be distinguished (figs. 10 and 11). The area underlain by this till is characterized by circular and linear features not associated with other tills. At least one new glacial lakebed has been discovered. Synoptic views with this degree of resolution are valuable geologic tools, even in Illinois.

The S190B frame can be enlarged several times while maintaining resolution (fig. 12). A crude land-use map can be compiled directly from visual photo interpretation of this frame (fig. 13). A general division into business, industrial, older residential, younger residential, and other areas can be made. Major transportation links stand out. Details of soil patterns associated with moraine systems can be seen in the open areas. The boundaries shown in figure 13 are interpretative boundaries and not political boundaries. Interpretation is based on degree of building coverage (industrial-business), abundance of trees (more – older residential; fewer – new residential), open space in urban areas, and farm land in rural areas.

Southern Illinois

Individual bedrock boundaries, where marked by cliffs or vegetation, can be mapped on Skylab 2 photographs of southern Illinois (figs. 14 and 16). Sketch maps show what geologic information can be extracted from each scale of photographs (figs. 15 and 17). Fault traces, outcrops, floodplain flow and meander patterns, disturbed ground, reclaimed and active strip mines, minor stream patterns, sinkholes, and major structural features can be distinguished. Stereovision is a valuable asset in making sketch maps from these photographs.

Fig. 8 - Skylab 2 frame 10-255, taken with the high-resolution color camera of of the S190A multispectral camera array over east-central Illinois, June 11, 1973.

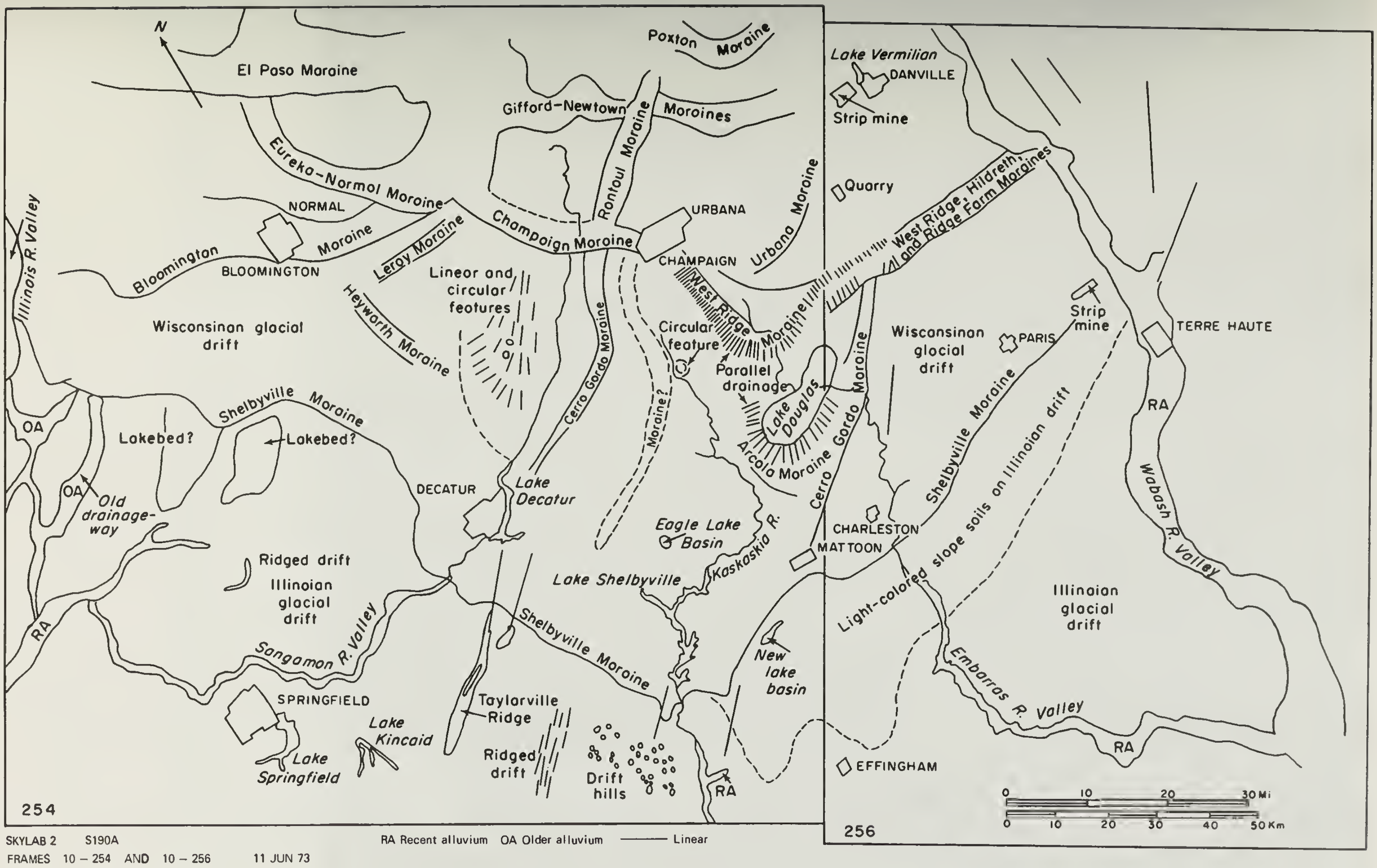


Fig. 9 - Geologic sketch map prepared from Skylab 2 frames 10-254 and 10-256, taken June 11, 1973, showing surficial glacial features in east-central Illinois.

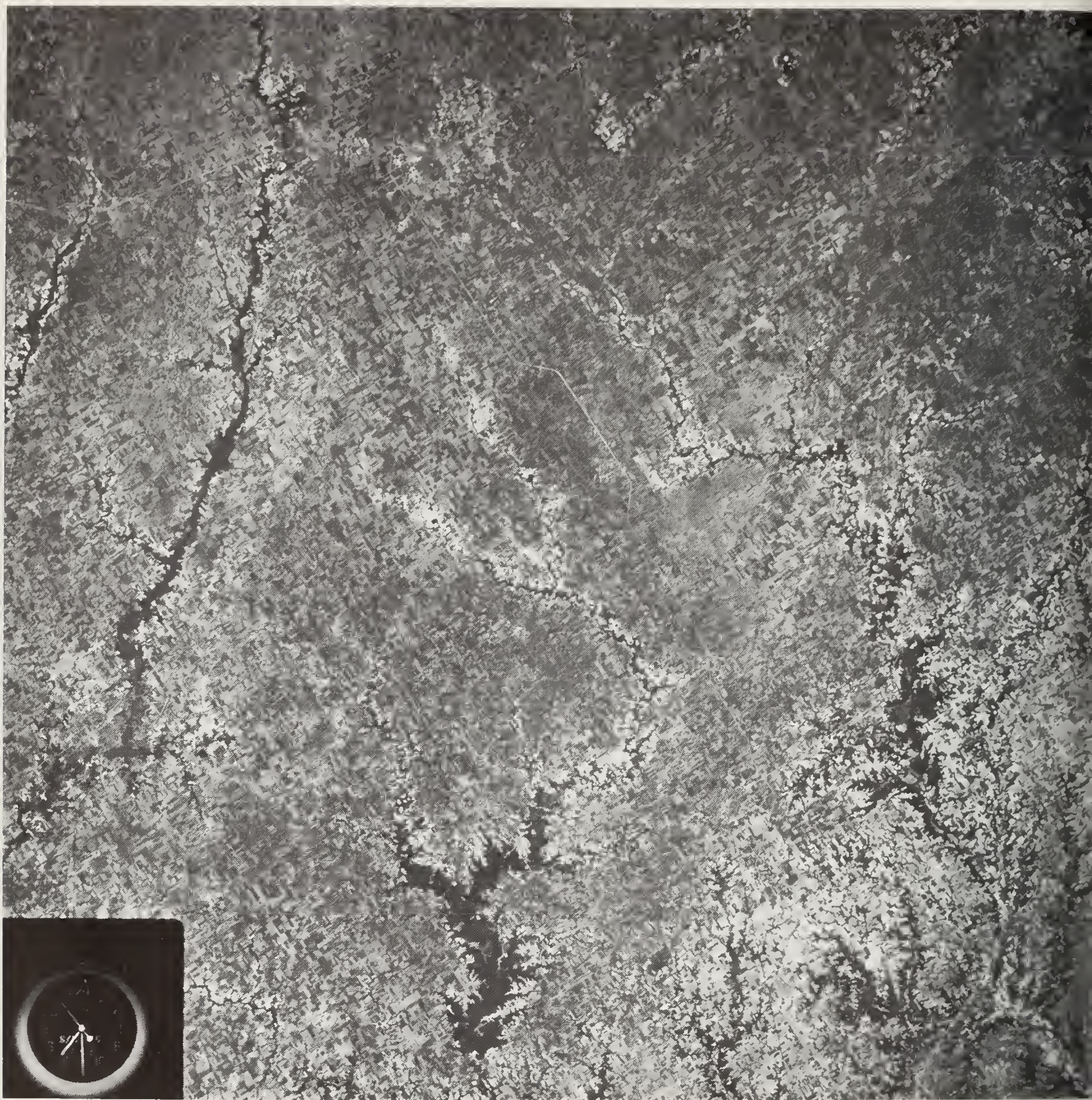


Fig. 10 - Skylab 2 frame 81-336, taken over east-central Illinois by the S190B 18-inch focal length earth terrain camera, taken June 11, 1973.

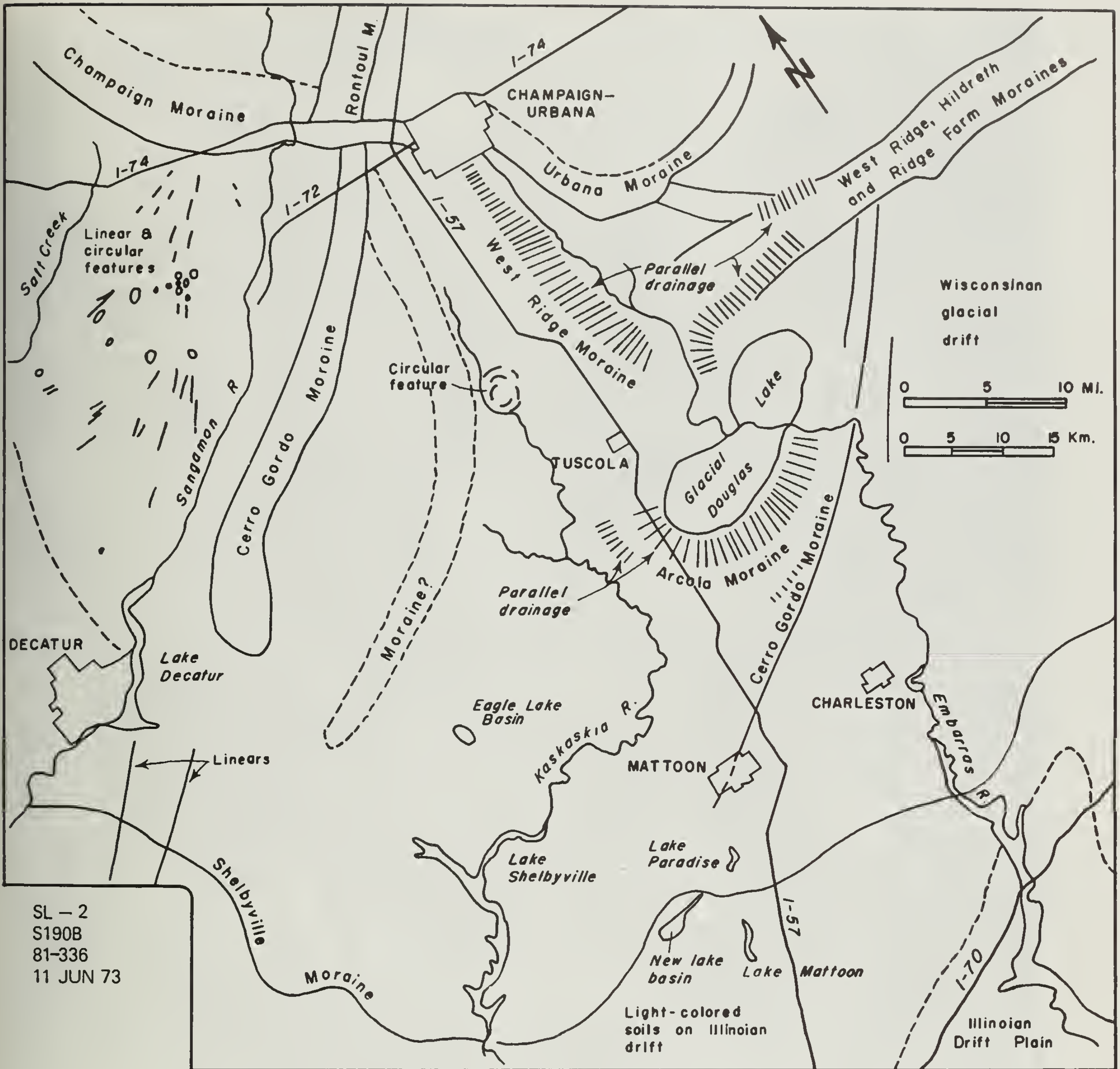


Fig. 11 - Geologic sketch map of east-central Illinois showing geologic detail interpreted from Skylab 2 frame 81-336, taken June 11, 1973. These photographs represent the highest resolution generally available from space platforms.

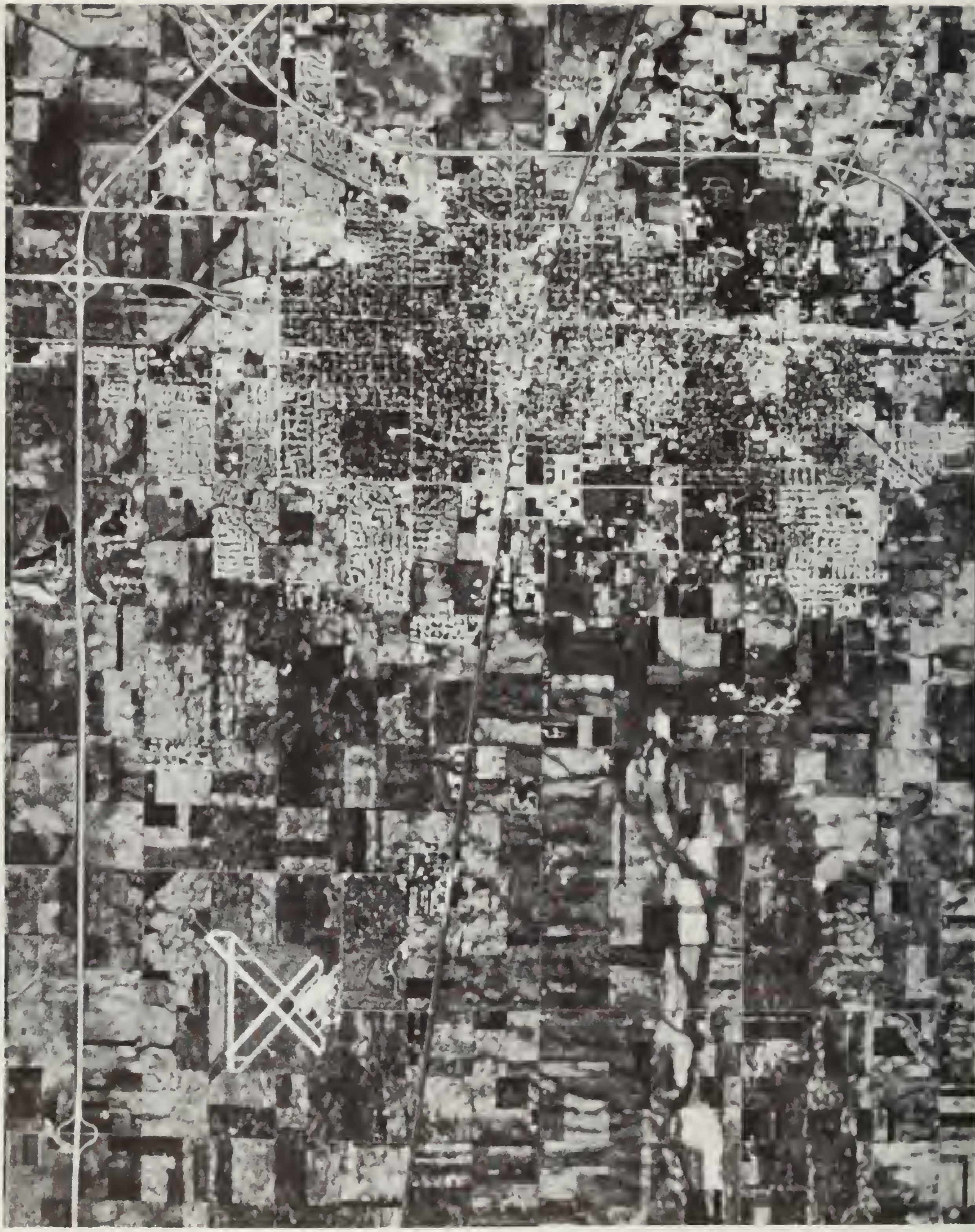


Fig. 12 - Enlargement of Skylab 2 S190B frame 81-336 showing the area of Champaign-Urbana, Illinois. This photograph was taken June 11, 1973, from a nominal altitude of 268 miles (433 km).

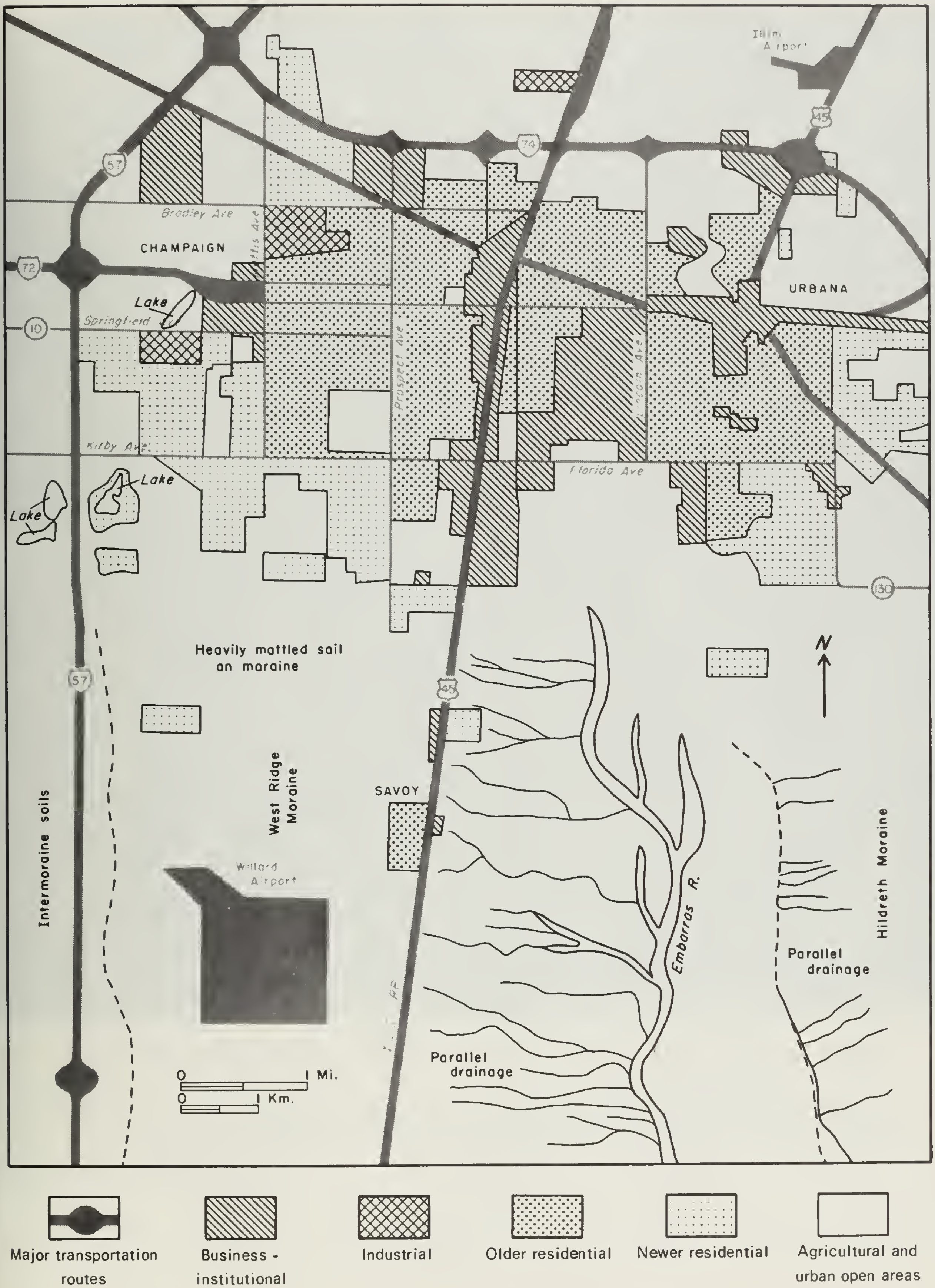


Fig. 13 - Generalized land-use map of Champaign-Urbana, Illinois, prepared from the enlargement of a portion of Skylab 2 frame 81-336, taken June 11, 1973.

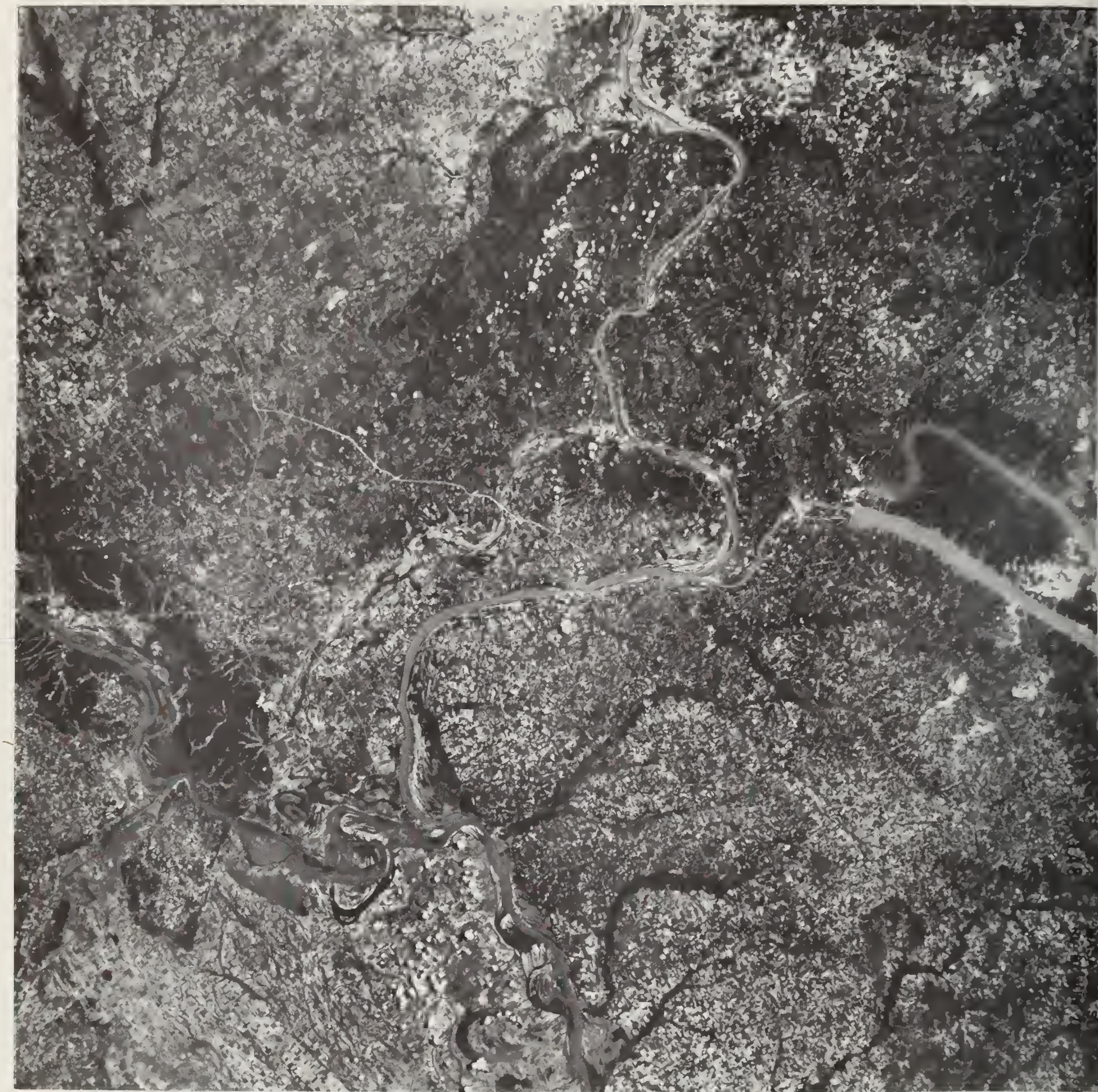
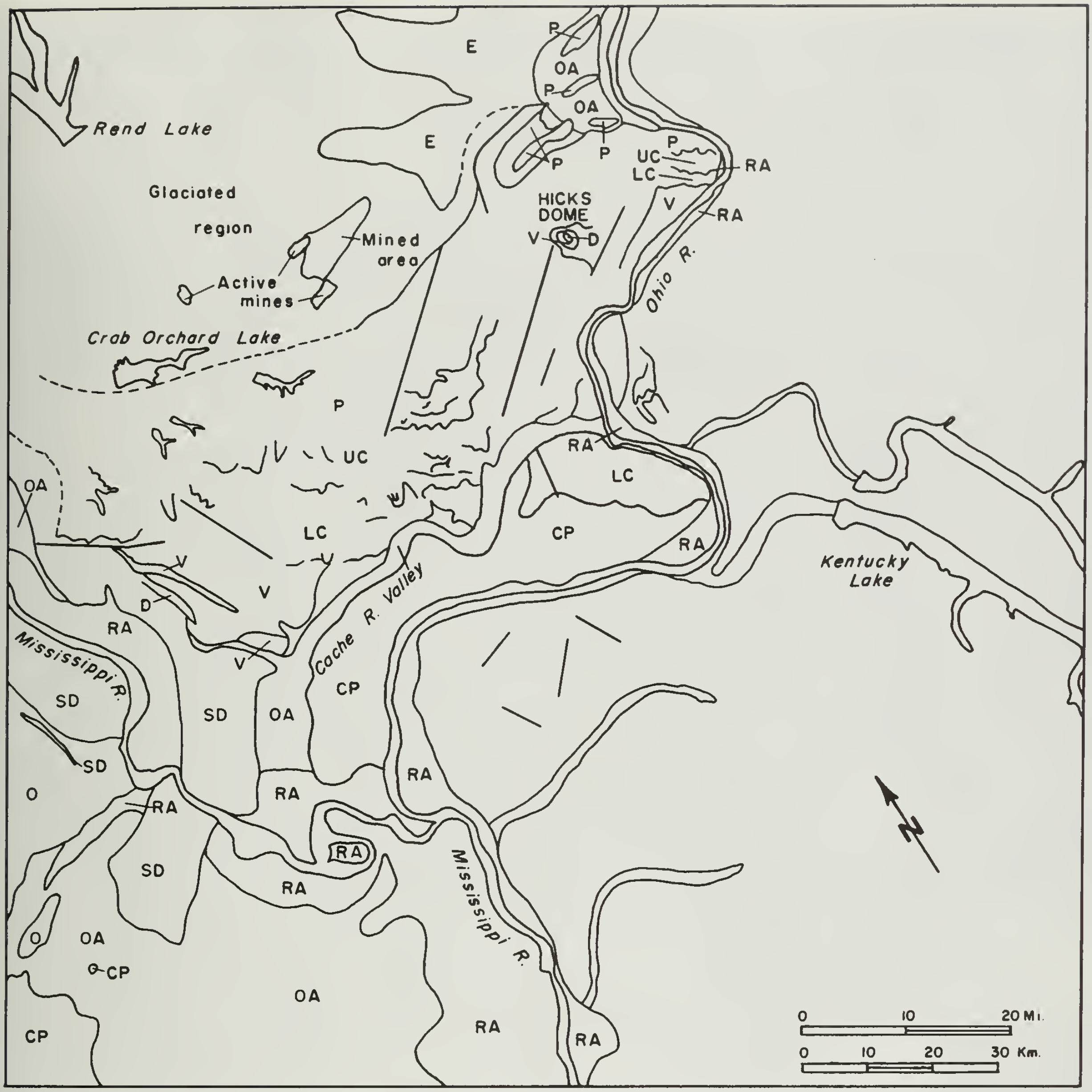


Fig. 14 - Skylab 2 frame 10-148, taken over southern Illinois June 9, 1973, with the S190A camera.

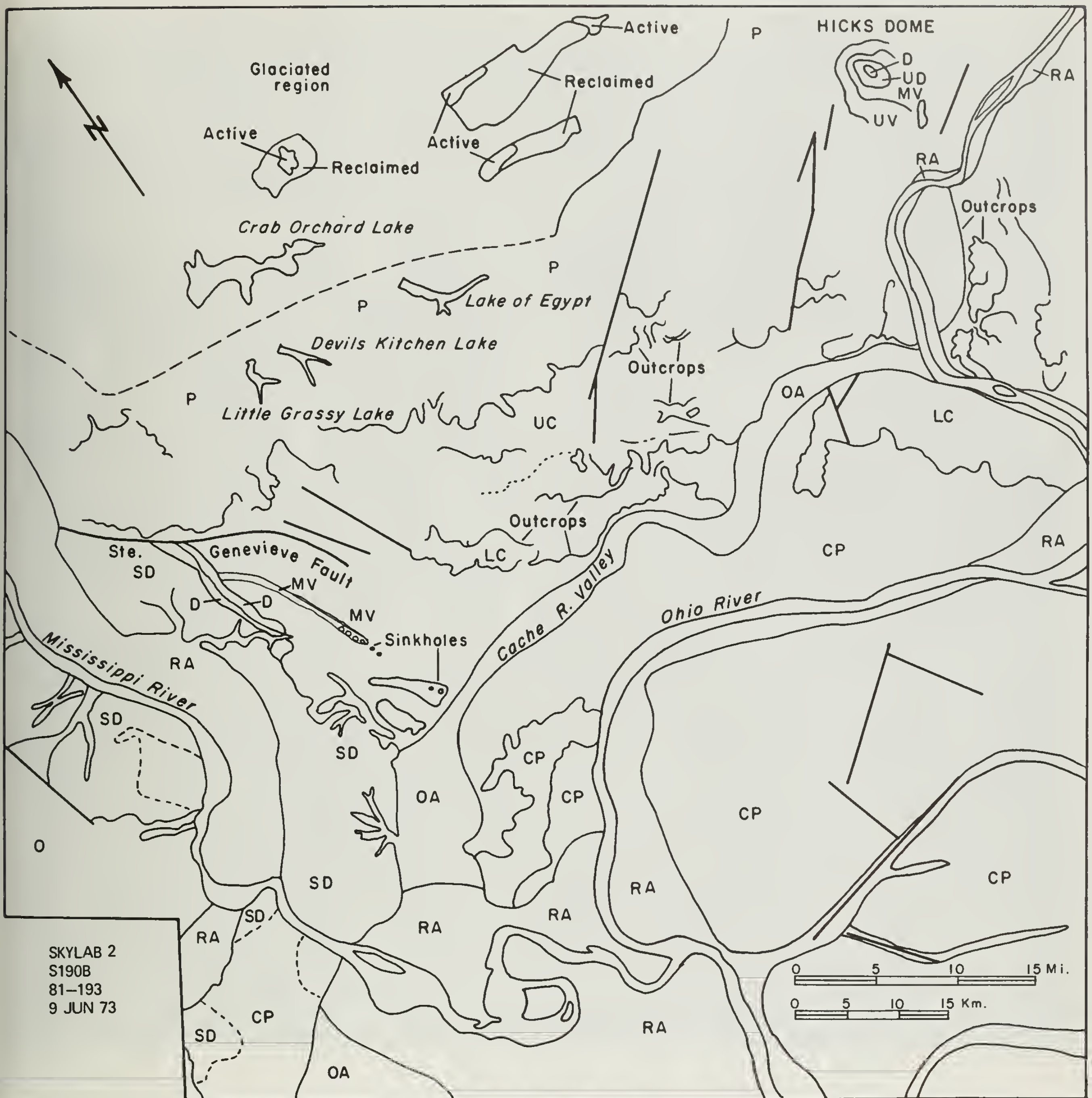


SKYLAB 2 S190A FRAME 10 – 148 9 JUN 73

RA	Recent alluvium	P	Pennsylvanian	SD	Silurian – Devonian
OA	Older alluvium	UC	Upper Chesterian	O	Ordovician
E	Equality Formation (Lake Saline)	LC	Lower Chesterian		
CP	Coastal plain sediments (Cretaceous – Tertiary)	V	Valmeyeran	——	Fault or linear
		D	Devonian		

Fig. 15 - Geologic sketch map of southern Illinois showing the details of bedrock geology that can be interpreted from Skylab 2 photographs. Frame 10-148, June 9, 1973.

Fig. 16 - Skylab 2 frame 81-193, taken over southern Illinois with the S190B camera June 9, 1973.



RA	Recent alluvium	UC	Upper Chesterian	UD	Upper Devonian (New Albany)
OA	Older alluvium — terraces	LC	Lower Chesterian	D	Devonian
CP	Coastal plain sediments (Cretaceous — Tertiary)	UV	Upper Valmeyeran (Aux Vases — St. Louis)	SD	Silurian and Devonian
P	Pennsylvanian	MV	Middle Valmeyeran (Salem — Springville)	O	Ordovician and older
				——	Fault or linear

Fig. 17 - Geologic sketch map prepared from frame 81-193, taken June 9, 1973, showing the maximum geologic detail available from Skylab photography.

The location of several major lineaments associated with faults can be seen on Skylab photos. However, many known faults do not appear as lineaments. Hicks Dome, a major structure in Hardin County, appears as concentric rings of trees and cleared land, depending on the type of rock cropping out. The geologic boundaries marked on the photo interpretation have not been related to specific units, because several formations crop out within the topographic feature mapped. Most of these are resistant cliff-forming sandstones, or in some cases limestones. The Cache River Valley, an abandoned channel of the Ohio River, shows up well. Soils associated with the flat-lying surface of glacial Lake Saline can be seen in the Saline River drainage basin (figs. 14 and 15).

The large areas strip mined for coal appear clearly and areas recently stripped can be separated from partially vegetated spoil piles. Sinkholes can be seen in the S190B telephoto photographs (figs. 16 and 17).

Overall Value

Skylab photographs can be used for general geologic mapping, locating mined and disturbed areas, mapping gross details of land use, flood mapping, and other geologic purposes in much the same way that standard aerial photographs are used. Some new features can be discovered even in well-mapped areas, and the value of Skylab photos in detailed mapping in unknown or poorly known regions is obviously great.

HIGH-ALTITUDE PHOTOGRAPHS

High-altitude (20+ km, 50,000 to 70,000 ft) photography is available for selected areas as a result of NASA underflights for certain earth resources observation investigations. An example of this type of photograph, taken over Cerro Gordo, Illinois, March 30, 1973, by an RB-57 aircraft, is illustrated in figures 18 and 19. Extreme details of soil patterns are visible on this scale photograph, but the area covered is only 17 miles (27 km) on a side and the synoptic overview is not as valuable as the overview from a space platform. Linear features and glacial moraines become difficult to pick out of the wealth of detail. Where available, these photographs constitute a useful tool for detailed investigations.

CONCLUSIONS

Preliminary comparisons of ERTS imagery, Skylab photography, and high-altitude aircraft photography of Illinois lead to the following evaluations of their use in geology.

1. Photographs or images of bare soil in the spring months yield the best results for interpreting most geological phenomena in Illinois. Summer and fall vegetation and winter snows generally hide significant geologic features, although light snow cover may enhance certain linear features.

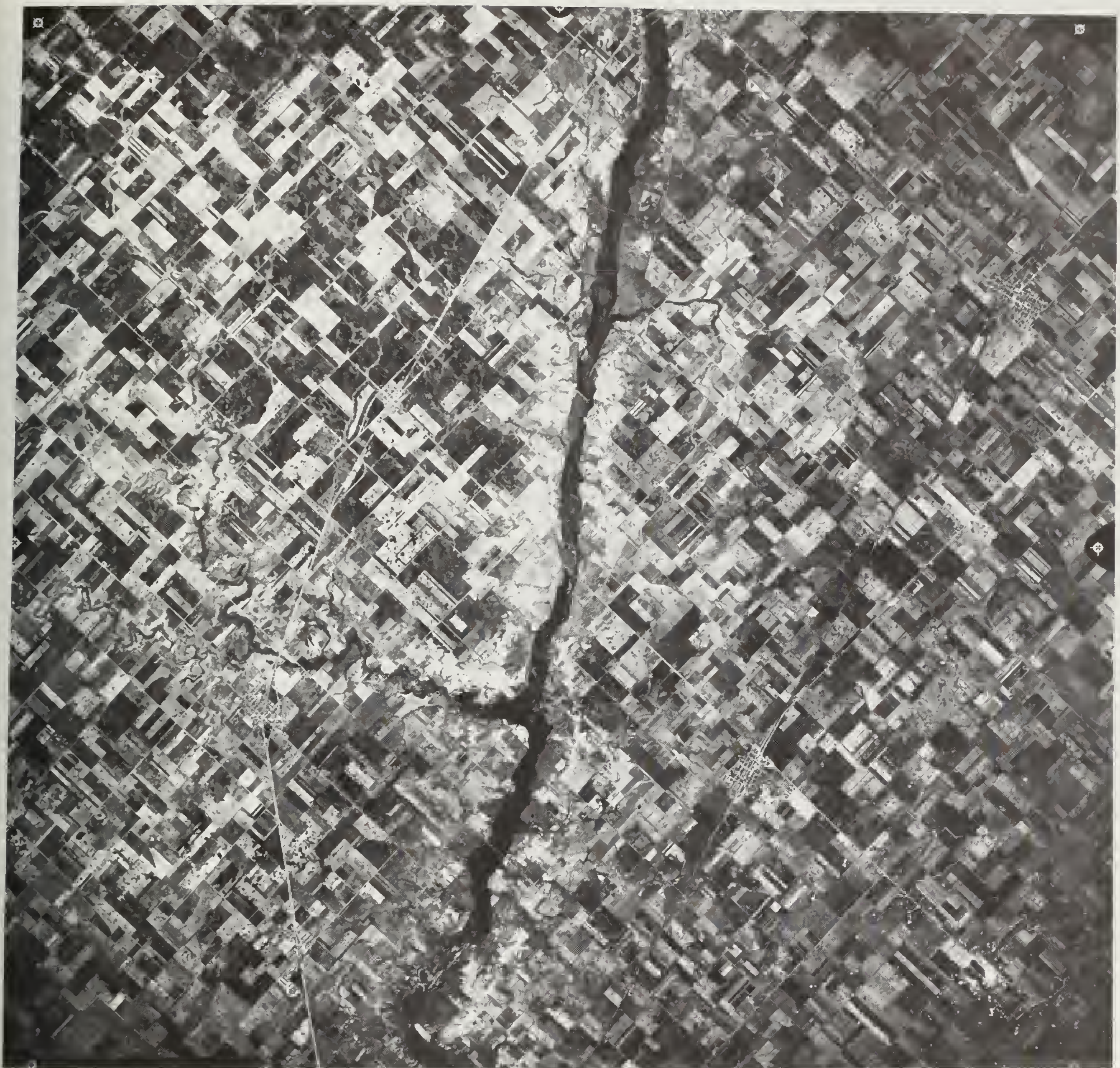


Fig. 18 - Photograph 9593 taken from an RB-57 aircraft March 30, 1973, over Cerro Gordo, Piatt County, Illinois. Great detail is present, but synoptic overview is limited.

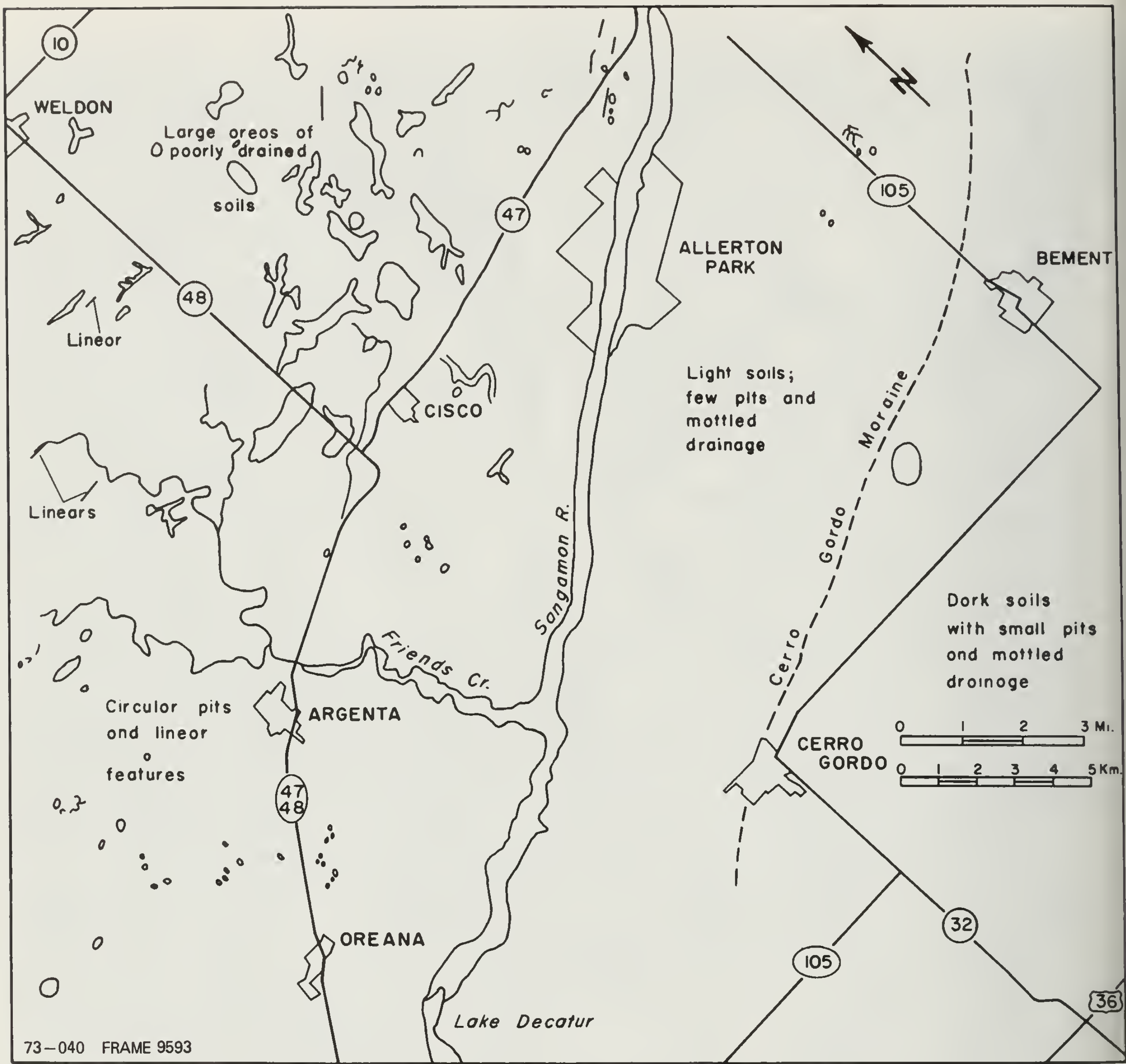


Fig. 19 - Geologic sketch map prepared from RB-57 high-altitude photograph 9593, March 30, 1973.

2. ERTS images are of limited value in Illinois because of low resolution. The repetitive views can be useful, however, in studying some dynamic phenomena such as flooding and sediment dispersal in Lake Michigan.

3. Synoptic views of high resolution, such as those provided by the Skylab EREP cameras, are valuable tools to aid in geologic mapping in Illinois. They cannot replace conventional methods but can be valuable aids in generalizing surficial phenomena and speeding up selection of sites for surficial examination and subsurface exploration. A few previously unknown geologic features have been found on Skylab photographs.

4. High-altitude photographs provide a wealth of detail, similar to that in conventional aerial photographs, but the synoptic overview, so valuable in space photographs, is limited. Where available, high-altitude photographs can be used to reduce the number of conventional photographs needed.

5. Continuing studies of present and future imagery and photography from space platforms will develop more applications to mapping and environmental studies in Illinois. Experimental studies in computer processing may result in operational programs to speed up use of these data.

6. Future space platforms may carry higher-resolution imaging equipment, and multiple platforms could provide data more often. Geostationary satellites, imaging through telescopes, could provide continuous imagery of the United States. Future manned missions and permanent manned orbital stations could provide photographic coverage of the entire country.

Undoubtedly the data now available are only a small fraction of what will be available in a few years, and geological scientists need to learn how to make use of applicable data in their investigations.

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APPENDIX

ANNOTATED LIST OF ERTS-1 IMAGES AND SKYLAB PHOTOGRAPHS

ERTS IMAGES

The following image identification numbers are of MSS images of Illinois that have less than 30 percent cloud cover. Images that have been examined in the Illinois State Geological Survey Remote Sensing Files have notes indicating quality, coverage, or special features. See figure 1 for location of nominal image centers. Images were taken between August 1972 and September 1973. Each frame has four bands: MSS 4 - blue-green; MSS 5 - red; and MSS 6 and 7 - infrared.

Center 24-31: Northeastern Illinois

Image identification	Date taken	Remarks
1017 16093	29Aug72	
1070 16041	01Oct72	Good Chicago and Lake Michigan shoreline
1088 16043	19Oct72	Clouds over Chicago and Lake Michigan
1124 16050	24Nov72	Some snow; good lake currents
1196 16050	04Feb73	Cloudy; lake turbidity shows
1250 16052	30Mar73	Chicago, lake ice, turbidity
1322 16045	10Jun73	Chicago and southern Lake Michigan
1358 16042	16Jul73	A few clouds
1376 16041	03Aug73	Shoreline currents; turbidity in lake
1394 16035	21Aug73	A few clouds
1448 16023	14Oct73	Good

Center 24-32: East-central Illinois

Image identification	Date taken	Remarks
1070 16043	01Oct72	Good
1088 16050	19Oct72	Good
1124 16052	24Nov72	Good; some moraines visible
1196 16052	04Feb73	High clouds and contrails
1250 16054	30Mar73	Partly cloudy
1286 16053	05May73	A few clouds
1322 16051	10Jun73	Moraines show well
1358 16045	16Jul73	Good; some clouds
1376 16043	03Aug73	A few clouds
1394 16042	21Aug73	A few clouds
1448 16030	14Oct73	Good

Center 24-33: Southeastern Illinois

Image identification	Date taken	Remarks
1052 16050	13Sep72	No clouds, but not a very clear image
1070 16050	01Oct72	Good; drainage patterns show well
1088 16052	19Oct72	Good
1106 16054	06Nov72	A few clouds
1178 16054	17Jan73	Haze; high water
1196 16055	04Feb73	Contrails and haze
1214 16060	22Feb73	Good
1250 16061	30Mar73	Partly cloudy
1286 16060	05May73	Good; flooding
1322 16054	10Jun73	Good
1358 16051	16Jul73	Good
1376 16050	03Aug73	Partly cloudy
1394 16044	21Aug73	Good
1448 16032	14Oct73	A few clouds

Center 24-34: Southern Illinois

Image identification	Date taken	Remarks
1034 16052	26Aug72	Good; trees reflect bedrock geology
1052 16052	13Sep72	Good
1070 16052	01Oct72	Good
1106 16060	06Nov72	Good
1124 16061	24Nov72	Good; some clouds
1178 16055	17Jan73	A few clouds
1214 16062	22Feb73	Good
1232 16063	12Mar73	Good; flooding
1286 16062	05May73	Good; flooding
1322 16060	10Jun73	Good; flooding
1340 16055	28Jun73	A few clouds; remains of flooding
1376 16052	03Aug73	Some clouds
1394 16051	21Aug73	Good
1538 16022	12Jan74	Partly cloudy; Ohio River flood

Center 25-30: Southern Wisconsin-Northern Illinois

Image identification	Date taken	Remarks
1017 16093	09Aug72	Good; Chicago-Rockford
1053 16093	14Sep72	Some clouds over Illinois
1071 16093	02Oct72	Some clouds; turbidity in Lake Michiga
1089 16095	20Oct72	A few clouds in Illinois
1143 16102	13Dec72	Snow; good
1215 16103	23Feb73	Snow; clouds
1305 16102	24May73	Hazy over Illinois
1323 16105	11Jun73	Includes very little of Illinois
1359 16094	17Jul73	Good
1395 16091	22Aug73	Clouds; turbidity in Lake Michigan

Center 25-31: Northern Illinois

Image identification	Date taken	Remarks
1017 16100	09Aug72	Good; Chicago not included
1071 16095	02Oct72	Good; Chicago and lake shore
1089 16102	20Oct72	Hazy; contrails
1143 16104	13Dec72	Snow; good
1215 16105	23Feb73	Snow; good
1305 16104	24May73	Partly cloudy
1323 16103	11Jun73	Good; a few clouds
1341 16102	29Jun73	Cloudy
1359 16100	17Jul73	Good
1395 16093	22Aug73	A few clouds
1449 16082	15Oct73	A few clouds
1557 16061	31Jan74	Good; a little snow

Center 25-32: Central Illinois

Image identification	Date taken	Remarks
1017 16102	09Aug72	Good; a few clouds
1071 16102	02Oct72	Good
1215 16112	23Feb73	Good
1305 16111	24May73	Good; a few clouds
1323 16105	11Jun73	Partly cloudy
1341 16104	29Jun73	Good
1359 16103	17Jul73	Good
1449 16084	15Oct73	Good
1557 16063	31Jan74	Good

Center 25-33: St. Louis region

Image identification	Date taken	Remarks
1071 16104	02Oct72	Good
1215 16114	23Feb73	Good
1251 16115	31Mar73	Some clouds; flooding
1305 16113	24May73	Good; flooding
1323 16112	11Jun73	A few clouds
1341 16111	29Jun73	Good
1359 16105	17Jul73	Good
1377 16104	04Aug73	A few clouds
1395 16102	22Aug73	Cloudy
1449 16091	15Oct73	Good
1557 16070	31Jan74	Good

Center 25-34: Southwestern Illinois-Southeastern Missouri

Image identification	Date taken	Remarks
1035 16112	27Aug72	
1071 16111	02Oct72	Good
1215 16121	23Feb73	
1251 16122	31Mar73	Good; flooding
1305 16120	24May73	Good; flooding
1323 16114	11Jun73	Some clouds
1359 16112	17Jul73	
1377 16111	04Aug73	Good
1395 16105	22Aug73	
1449 16093	15Oct73	A few clouds
1557 16072	31Jan74	Good

Center 26-30: Southwestern Wisconsin-Northwestern Illinois

Image identification	Date taken	Remarks
1018 16151	10Aug72	A few clouds
1036 16152	28Aug72	Good
1054 16151	15Sep72	A few clouds
1144 16160	14Dec72	Snow; good
1162 16155	01Jan73	Snow; good
1234 16162	14Mar73	Good
1342 16154	24Jul73	
1378 16151	05Aug73	Good; a few clouds
1490 16133	16Oct73	Good
1576 16111	19Feb74	Snow enhancement

Center 26-31: Western Illinois-Rock Island

Image identification	Date taken	Remarks
1018 16153	10Aug72	Good
1036 16154	28Aug72	Good
1054 16154	15Sep72	Partly cloudy
1126 16163	26Nov72	
1144 16163	14Dec72	Snow
1162 16161	01Jan73	Good; flooding
1216 16164	24Feb73	Snow; flooding
1234 16165	14Mar73	Good; flooding
1378 16153	05Aug73	Good
1504 16133	09Dec73	Snow and clouds

Center 26-32: Western Illinois

Image identification	Date taken	Remarks
1018 16160	10Aug72	Good
1036 16161	28Aug72	Good
1144 16165	14Dec72	Clouds; snow
1162 16164	01Jan73	Good
1216 16170	24Feb73	Good
1234 16171	14Mar73	Good; flooding
1306 16165	25May73	Clouds; flooding
1342 16163	30Jun73	Haze
1378 16160	05Aug73	Good

SKYLAB PHOTOGRAPHS

Roll	Wavelength, film
7	Blue-green, black and white
8	Red, black and white
9	Color infrared
10	High-resolution color
11	Near infrared, black and white
12	Far infrared, black and white
81, 88	High-resolution color from 18-inch S190B camera

S190A Multispectral Camera Array, 6 cameras (rolls 7-12), 70 mm format

Skylab 2

Rolls	Frame	Area	June 1973
9, 10	145	St. Louis	
9, 10	146	Jackson County	
9, 10	147	Cairo	
9, 10	148	Southern Illinois	
9, 10	149	Hardin County	
7, 8, 11, 12	137	St. Louis	
7, 8, 11, 12	138	Jackson County	
7, 8, 11, 12	139	Cairo	
7, 8, 11, 12	140	Southern Illinois	
7, 8, 11, 12	141	Hardin County	
9, 10	251	Rock Island	
9, 10	252	Galesburg	
9, 10	253	Peoria	
9, 10	254	Bloomington	
9, 10	255	Decatur	
9, 10	256	Champaign	
9, 10	257	Wabash River	
7, 8, 11, 12	235	Rock Island	
7, 8, 11, 12	236	Galesburg	

Skylab 2 continued

Rolls	Frame	Area	June 1973
7, 8, 11, 12	237	Peoria	
7, 8, 11, 12	238	Bloomington	
7, 8, 11, 12	239	Decatur	
7, 8, 11, 12	240	Champaign	
7, 8, 11, 12	241	Wabash River	

Skylab 3

Rolls	Frame	Area	September 1973
7-12	195	Quincy	
7-12	196	Pekin	
7-12	197	Peoria	
7-12	198	Joliet	
7-12	199	Chicago	
7-12	200	Southeastern Lake Michigan	

S190B 18-inch Earth Terrain Camera, 4½ x 4½ inch format

Skylab 2

Roll	Frame	Area	June 1973
81	190	St. Clair County	
81	191	Randolph County	
81	192	Jackson County	
81	193	Southern Illinois	
81	194	Massac County	
81	195	Kentucky Lake	
81	330	Muscatine, Iowa	
81	331	Galesburg	
81	332	Peoria	
81	333	Bloomington	
81	334	Decatur	
81	335	Decatur-Champaign	
81	336	Champaign	
81	337	Mattoon-Charleston	
81	338	Terre Haute, Indiana	

Skylab 3

Roll	Frame	Area	September 1973
88	218	Quincy	
88	219	Pekin	
88	220	Peoria	
88	221	Joliet	
88	222	Chicago	
88	223	Southeastern Lake Michigan	

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